Technical Summary

STUDY TITLE: "Pilot study of aerial high-definition surveys for seabirds, marine mammals and sea turtles"

REPORT TITLE: "High-resolution aerial imaging surveys of marine birds, mammals, and turtles on the US Atlantic Outer Continental Shelf: utility assessment, methodology recommendations, and implementation tools"

CONTRACT NUMBER: M10PC00099

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREA(S): Atlantic Outer Continental Shelf

FISCAL YEAR(S) OF PROJECT FUNDING: 2011–2012

COMPLETION DATE OF REPORT: October 16, 2012

COSTS: $988,289.46

PROJECT MANAGER(S): Caleb Gordon and Christian Newman

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KEY WORDS: High-resolution imaging, marine wildlife survey methodology, offshore wind energy development, wind-wildlife interactions, seabirds, marine biology, marine mammals, sea turtles

BACKGROUND: To develop the vast offshore wind energy resources located on the US Atlantic Outer Continental Shelf (AOCS), new survey methodologies are needed to fill existing data gaps and solve methodological problems associated with conventional surveys of birds, marine mammals, and sea turtles. Pioneering aerial high-resolution imaging surveys in Europe have suggested that this new technique represents a safe, scientifically robust, and cost-effective solution for gathering the type of data needed on birds, marine mammals, and sea turtles. Research, development, and experimentation is required in order to determine the specific applicability, and optimal methodology for applying this method on the US AOCS for surveys of marine birds, mammals, and turtles in support of US offshore wind energy development

OBJECTIVE: To develop and test a methodology for conducting surveys of birds, marine mammals, and sea turtles in the offshore environment using state of the art survey techniques that are efficient and provide high quality, reproducible data.

DESCRIPTION: Our approach to satisfying this objective was three-pronged, as follows:

1) *Assemble a project team composed of world-leading experts in the various specialized fields of study entailed in the study's scope*—The specific personnel and organizations that comprised the project team collectively encompassed renowned proficiency in aviation (manned and unmanned aircraft systems), high-resolution imaging and image processing, marine biology (birds, marine mammals, sea turtles), and European experience with high-resolution imaging surveys as applied to offshore wind-wildlife studies. The collective expertise of our team enabled us to develop state-of-the-art high-resolution imaging systems for use in experimentation. Our team's expertise also enabled us to perform the evaluation and recommendation components of this study, with experts in their respective fields gathering and synthesizing current information from technical literature and current commercial practice, and then evaluating experimental results to assess effectiveness and develop recommendations.

2) *Conduct experimental surveys*—The experimental field studies we conducted offshore of Oak Island, North Carolina during May 2011 served as the core of this study, providing the data from which most of the evaluations, protocols, and software deliverables of this study were derived. We applied an experimentalist paradigm to these field surveys, performing offshore aerial high-resolution wildlife imaging survey trials with a variety of imaging treatment combinations (e.g., image resolution, camera tilt, flight altitude), alongside control surveys conducted with conventional survey methodologies using expert visual observers aboard a boat (vessel) and a low flying aircraft. We also conducted a variety of smaller scale imaging survey trials using an unmanned aircraft system (UAS).

3) *Manually review high-resolution imagery*—Normandeau conducted a comprehensive, manual review of all of the imagery gathered during the imaging experiments with the manned aircraft, to discover and extract all images of animals captured in the surveys along with all relevant metadata. This review, and the resulting archive of animal images, provided essential raw material for the various methodological and technological evaluations we conducted and a set of implementation tools we developed, and that are presented in this report.

SIGNIFICANT CONCLUSIONS: Our findings suggest the following conclusions:

- High-resolution digital aerial imaging represents a safe, scientifically robust, and cost-effective solution for gathering data to characterize the spatiotemporal abundance and distribution patterns of birds, marine mammals, and sea turtles on the AOCS.
- With respect to marine animal detection and density estimation, we conclude that digital methods are generally superior to conventional, visual-based survey methods, with the possible exception of surveys for baleen whales.
- With respect to the determination of marine animals' taxonomic identity, we conclude that digital methods using 2.5 cm image resolution or finer (especially 1.5 cm resolution or finer) yield more reliable determinations of animals' taxonomic identity than visual observer based aerial survey methods. Vessel-based methods retain an advantage for targeted, small-scale

surveys of particular species that are extremely difficult to distinguish based on digital images alone.

STUDY RESULTS: The varied original synthesis, research, and methodological development initiatives of this project produced a variety of results as follows:

- Our evaluations based on literature review and analysis of original data from field experimentation resulted in a variety of specific technological and methodological recommendations for conducting high-resolution digital offshore wildlife surveys on the AOCS. The specific areas evaluated, and for which technologies and/or methodologies are recommended include the following:
    - Survey aircraft
    - Cameras and optics
    - Imaging parameters (e.g., exposure times, shutter type)
    - Camera mounts
    - Onboard digital recording devices
    - Camera control and calibration procedures
    - Automated animal recognition algorithms
    - Image resolution
    - Camera angles
    - Sun glare mitigation
    - Flight altitude
    - Survey frequencies
    - Survey transect patterns
    - Use of single images (stills) versus multiple images (video) for animal identification

- We developed two algorithms that can be used to automate the detection of animals in high-resolution marine wildlife survey imagery: one that uses shape and contrast features, and another that uses color-related features to distinguish animals from a background of water. The former was prone to high false negative rates (missed animal detections), and the latter was prone to high false positive rates (failure to eliminate very many empty frames), hence both would require further research and development to achieve viability. An effective automated animal detection algorithm is an essential ingredient for conducting cost-effective high-resolution marine wildlife imaging surveys, particularly at spatial scales greater than the size of single commercial offshore wind energy projects. Quality control checks, consisting of manual review of subsets of survey imagery to determine false positive and false negative rates of the automated animal detection algorithms, are a vitally important component of conducting scientifically valid and robust marine wildlife surveys using high-resolution aerial imagery.
- We developed protocols for conducting aerial high-resolution marine wildlife imaging surveys on the AOCS, intended as a guide to the basic hardware, staffing, methodological, and budgetary requirements entailed in conducting such surveys. These protocols describe specific imaging hardware, survey platform, survey pattern and frequency, task structure, labor breakdown by staffer type, and annualized total costs under a variety of specified costing assumptions for complete imaging survey studies extending from survey planning

and design up to, and including, data analysis and reporting. We developed three distinct protocols corresponding to three distinct spatial scales that may be of interest for marine wildlife surveys on the AOCS, as follows:

- Whole AOCS scale—This protocol is intended to cover the entire federally regulated portion of the AOCS where offshore wind development is most desirable based on wind resources, and most plausible using existing turbine foundation technology. This area extends from Maine to Florida, from the states' seaward boundaries (generally 3 nautical miles from shore) up to the 30 m isobath, and measures 210,000 km^2. At this scale, coarse-scale broad baseline data gathering objectives are most likely, which drove our selection of semiannual survey frequency, 10% subsampling, and 2 cm image resolution. This protocol was developed specifically for implementation using either of two existing US federal government wildlife survey aircraft fleets; and the estimated annual cost of implementing this protocol is $1.9 to $2.2 million.
- Regional scale. This protocol is intended to cover subsets of the entire AOCS region described above corresponding to single BOEM planning regions (e.g., northeast, mid-Atlantic, southeast), or to the portions of the AOCS offshore of single states, or consortia of several states, measuring on the order of 25,000 km^2. At this scale, data gathering objectives are likely to be finer than at the AOCS scale, but still somewhat broad in scope, along the lines of a regional baseline study. This drove our selection of quarterly survey frequency, 10% subsampling, and 1 cm image resolution. This protocol was developed assuming that a single charter aircraft would be used to conduct the surveys: and the estimated annual cost of implementing this protocol is roughly $880,000.
- Project scale. This protocol is intended to cover individual, commercial-scale offshore wind energy facilities sited within the AOCS region described above, measuring on the order of 150 km^2. At this scale, data gathering objectives are likely to be more refined, and compliant with individual leasing and permitting environmental risk/impact analysis requirements. This drove our selection of 8x/year survey frequency, 20% subsampling, and 1 cm image resolution. This protocol was developed assuming that a single charter aircraft would be used to conduct the surveys. The estimated annual cost of implementing this protocol is roughly $370,000.

- We developed a sun glare mitigation planning tool consisting of a formula for calculating angular deviation from the glint spot (ADGS)—for any geoposition at any time—using easily accessible input data on solar position, flight direction, and camera tilt. The mitigation of sun glare is a critical consideration for any high-resolution offshore wildlife imaging survey protocol on the AOCS because excessive glare renders images useless for wildlife data gathering. We developed the glare mitigation tool by first using our experimentally gathered imagery to characterize a glare threshold, above which animals cannot be effectively detected in images. We then determined that this threshold is crossed when the camera is oriented at less than 67° angular deviation from the glint spot, which is defined as the camera orientation at which the camera would be pointed directly at the sun's reflection on the water's surface at a given geoposition at a given moment in time. We conducted simulations to demonstrate that using fixed camera angles, the amount of low glare daylight hours available for surveys is heavily restricted on the AOCS, but can be roughly doubled by

using a mount that can allow the cameras to be alternated between 44° rear tilt and 44° forward tilt in flight, with aircraft flying transects alternating between east to west, and west to east. All of our protocols were developed assuming that this particular mount configuration is used for sun glare mitigation.

- We developed a taxonomic guide to the utility of high-resolution aerial wildlife imaging surveys on the AOCS. This guide is intended to inform readers about the specific taxa for which they should, and shouldn't expect to obtain useful data using high-resolution aerial imaging survey methodology, as well as various behavioral and appearance factors of the animals that influence the nature and quality of the data that can potentially be obtained. Although high-resolution aerial imaging survey data cannot satisfy all of the data gathering requirements for birds, marine mammals, and sea turtles associated with offshore wind energy development on the AOCS, the taxonomic breadth of the this technique is a compelling and attractive feature. In the taxonomic guide, we identify 84 species of birds, 35 cetaceans, and five sea turtles, comprising all of the species in these groups that occupy any portion of the region of interest for any portion of the year, for which high-resolution aerial imaging surveys are expected to provide useful data.

STUDY PRODUCT(S):

Normandeau Associates, Inc. 2012. High-resolution aerial imaging surveys of marine birds, mammals, and turtles on the US Atlantic Outer Continental Shelf: utility assessment, methodology recommendations, and implementation tools. A final report for the U. S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement. Contract # M10PC00099. 378 pp. plus supplemental materials

Willmott, J. R., and C. E. Gordon, (*in prep*). Comparison of digital and visual observer-based methods for surveying birds, turtles, and mammals in marine environments. Intended for submission to a peer-reviewed technical journal.

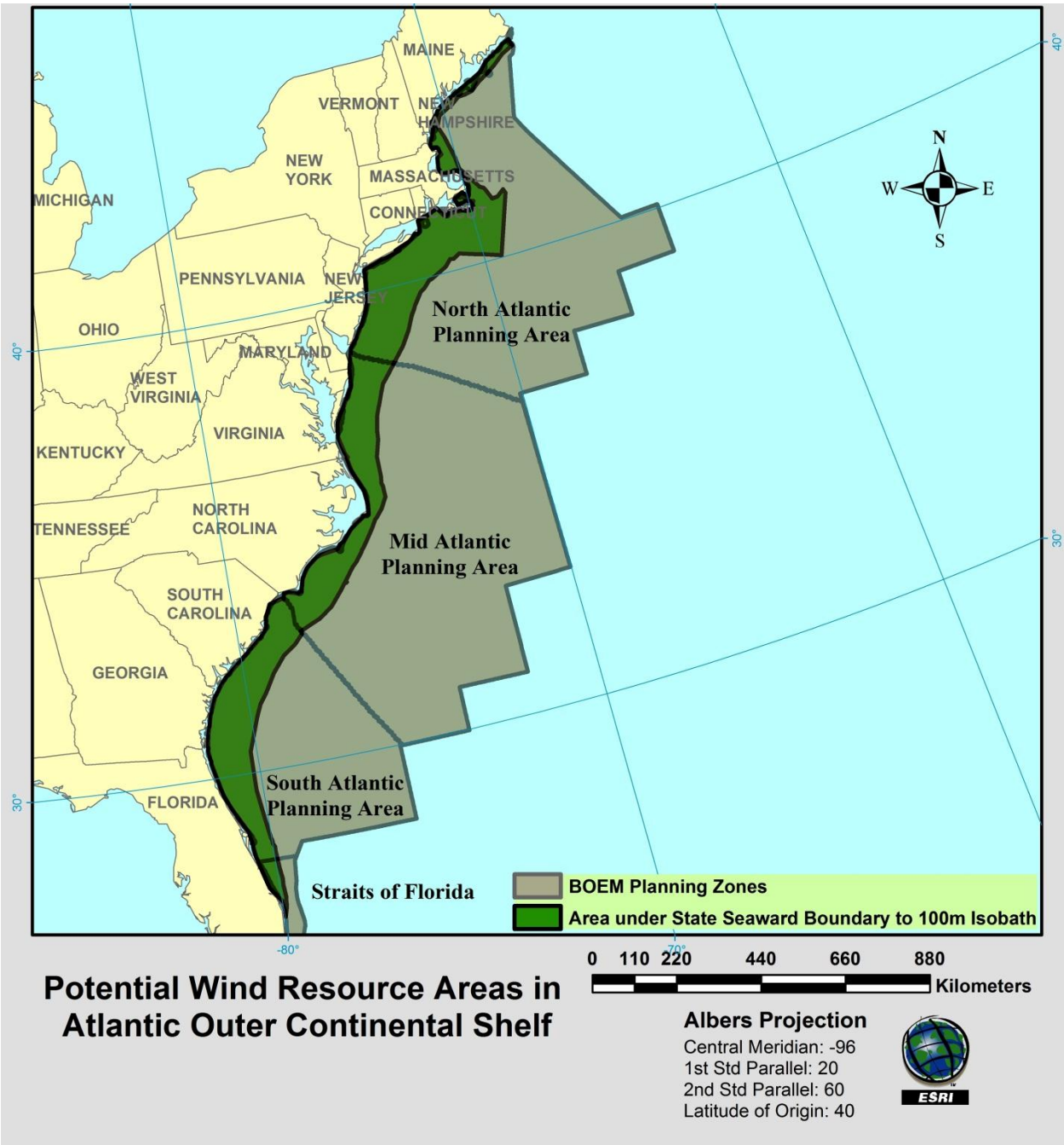

Figure 1. Map of study area.

[*] P.I.'s affiliation may be different than that listed for Project Manager(s).